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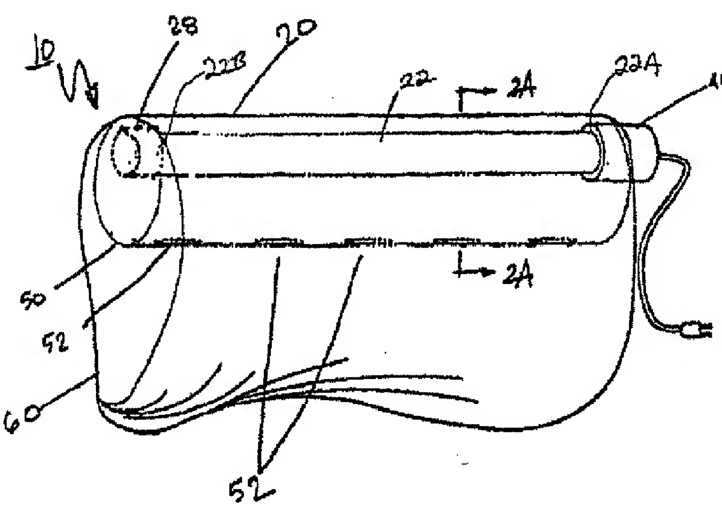

(57) Abstract

An inflator (20) delivering gases to an inflatable member (60), such as used in an inflatable seat belt or air bag includes an inner member (22), preferably a flexible non-metallic tube, that confines a propellant. An ignition assembly (40) ignites the propellant using a pressure wave that propagates along the length of the propellant within the inner member (22). Inflation gases are generated from combustion of the propellant and pass through the tube (22) that confines the propellant. The inflation gases then enter an outer member (50), preferably a flexible, non-metallic member, that covers the inner member and effectively functions as a manifold. Inflation gases are metered through the outer member (50) to fill the inflatable member (60). The inflator may be adapted for use in a variety of applications, including passenger and driver side air bags, head bags in roof rails, air bags in knee bolsters, side impact trim air bags, and external pedestrian air bags.

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PYROTECHNIC INFLATOR FOR A VEHICLE

FIELD OF THE INVENTION

The present invention generally relates to a pyrotechnic device for producing gases to inflate a device, such as an air bag or inflatable seat belt for a vehicle. The invention also relates to a inflatable safety system for a vehicle that incorporates such a device.

BACKGROUND

Conventional inflators used in vehicles typically include a squib (ignitor), a booster material, a propellant bed, and a filter. These elements are encased in a metal housing that serves as a combustion chamber in which pressure rises until seals on output ports rupture, and the generated gas is filtered and flows into an inflator, such as an air bag or inflatable seat belt. The combustion chamber maintains a relatively constant pressure until the propellant burns out, thereby producing sufficient gas to fill an inflatable cushion, such as in an air bag or inflatable seat belt. In such conventional inflators, ignition of the combustion bed typically is caused by heat and hot particles generated by ignition of the booster material with a squib.

Alternatively, it is generally known to use pyrotechnic lines, such as Rapid Deflagrating Cord (RDC), to propagate ignition of a pyrotechnic material. For example, outside the automotive arts, pyrotechnic transmission line has been used in the mining industry and in military applications for remote triggering of explosive systems. RDC has also been used in metal cutting to allow release of packaged systems. Such material has also been used in rocket stage separation and aircraft crew ejection systems.

Conventional inflators for vehicles are often used to inflate air bags mounted in the steering wheel (driver side) and near the glove compartment (passenger side) to help reduce the severity of injuries during a head-on

collision. More recently, some automotive manufacturers have mounted inflatable restraint systems in other locations to help reduce the severity of injuries resulting from other types of collisions. For example, air bags are now being placed adjacent the sides of the driver and front seat passenger and above the side windows to reduce injury resulting from side impact collisions. In the future, inflatable restraint systems may be developed for other locations, such as around the exterior of a vehicle.

As the use of inflatable restraint systems in such different locations increase, it becomes necessary to address particular design considerations. For example, curtain inflators, disposed above side windows, must be able to uniformly inflate a relatively long and narrow inflatable cushion. While a possible solution for this design concern is to use a metal pipe to distribute inflation gas within the cushion, such an approach increases overall cost and may implicate safety concerns.

Regardless of the application, commercially viable inflators must be reliable and cost competitive. In this regard, the propellant, filter and metal housing of conventional inflators contribute substantially to overall cost. Further, the metal parts of conventional inflators may limit application in alternative locations now being considered, such as head bags in roof rails, knee bolsters, side impact trim air bags, and external pedestrian air bags, and may limit use in other applications developed in the future.

Accordingly, there is a need to provide an inflator that is both reliable and cost effective for a variety of applications. There is also a need to provide an inflator that avoids or reduces the use of metallic or other relatively hard materials that may pose a safety hazard.

SUMMARY OF THE INVENTION

In accordance with the present invention, an inflator is provided that generates inflation gases for delivery to an inflatable member, such as an air bag or inflatable seat belt. The inflator includes a propellant for generating the

inflation gases when activated by an ignition assembly, such as a conventional squib.

The inflator according to the invention includes an inner member, preferably a non-metallic tube, that surrounds and confines a propellant. In one embodiment, a seal covers a number of holes spaced at predetermined distances from each other along the length of the tube, which seal ruptures once the internal pressure reaches a predetermined pressure. Alternatively, the surface of the tube is configured to rupture at particular areas once such a predetermined internal pressure is reached. The inner member may be rigid or flexible, and may be comprised of a knitted fabric or other resilient material.

Preferably, the propellant has a composition that sufficiently oxidizes to avoid the presence of toxic gases after combustion is completed, and that converts a high proportion of the original propellant mass to inflation gas leaving minimal residual solids. In one embodiment, the propellant is an elongated solid having a center bore that extends along the axis of the propellant. Additionally or alternatively, the outer surface of the propellant and the inner surface of the tube that confines the propellant define a gap that extends along the length of the propellant. In either or both cases, the gap and the center bore facilitate propagation of a combustion wave along the length of the elongated propellant. That is, when the propellant is ignited at one end thereof, a combustion wave (pressure wave) is created that propagates through the length of the interior of the tube, resulting in the combustion of the elongated propellant along a linear path defined by the length of the propellant. The inner member that confines the propellant then helps sustain combustion of the propellant by maintaining a sufficiently high pressure within its interior.

According to another aspect of the invention, the inflator further includes an outer member, preferably a tube, that houses at least substantial portions of the inner member and propellant. The outer member can be rigid or it can be flexible, e.g., made of a coated fabric or the like. The outer member directs and

controls flow of inflation gases to an inflatable member, such as in air bag or seat belt. In one embodiment, the outer member includes one or more holes through which inflation gases can pass after being released from the inner member. The outer member regulates the rate, pressure and direction of the inflation gases as they are released into the inflatable member. Like the inner member, the outer member is also preferably made of a non-metallic material that reduces its cost and size.

The outer member serves to prevent an unacceptable rate of filling or pressurization of the inflatable member with the inflation gases generated by the propellant. Because of the relatively rapid propagation of the combustion wave, inflation gases flow from the inner member into the outer member very rapidly to fill the outer member to a peak pressure. These gases stored in the outer member can then readily pass through several holes provided on the surface of the outer member at substantially the same rate, with the time of passage of inflation gases through such holes being relatively independent of the propagation rate in the pressure tube. Thus, the outer member functions as a manifold.

When applied in an inflatable safety system for a vehicle, the inflatable member surrounds the outer tube, and therefore receives such inflation gases along its length at substantially the same rate to uniformly fill an inflatable along its length at substantially the same time. This uniform receipt of inflation gases results in the inflator filling the entire inflatable member. Such an inflatable member may be used in a variety of applications.

In operation, an ignition assembly ignites the propellant at an end thereof. A pressure (combustion) wave then propagates rapidly along the length of the propellant within the inner member which confines the propellant. Inflation gases are generated and pass through holes or ruptures in the inner member after a predetermined internal pressure is reached. The inner member is sufficiently strong to resist any unintended structural rupturing or breaking thereof. Inflation

gases reach the holes in the outer member, which thereby meters the release of the gases at a desired rate, pressure and distribution as they fill the inflatable member. The inflator according to the invention may be used advantageously in a variety of applications, including without limitation, driver side air bags, passenger side air bags, head bags in roof rails, knee bolsters, side impact trim air bags, and external air bags.

The present invention provides several advantages. For example, in contrast to many conventional inflators, the inflator according to the invention utilizes a shock wave principle to ignite the propellant directly and propagate the ignition through the entire length of the propellant bed. Thus, the inflator initiates the generation of inflation gases from combustion of the propellant without the need for a booster propellant. The inner member controls the generation of these gases, and the outer member controls and directs the release of inflation gases into the inflatable member, thereby avoiding the need of a metal combustion housing. Further, depending on the composition of the propellant, the need for a metallic filter component may also be avoided. As a result the invention utilizes fewer components, thereby reducing the overall material and assembly cost of the inflator.

Additionally, the use of flexible, relatively soft, (for example, primarily non-metallic components) not only reduces cost, but also facilitates compliance with safety considerations, such as U.S. standard FMVSS 201.

In addition to having fewer parts, the inner member and the outer member can be made of non-metallic materials thereby also reducing the cost of the inflator. According to one aspect of the invention, uniform filling of an elongated inflatable is achieved through the use of the spaced holes in outer member, which regulate the flow of inflation gases in connection with filling the inflatable.

Additional advantages of the present invention will become readily apparent from the following discussion, particularly when taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIGURE 1 is a perspective view of an inflatable safety system according to one embodiment of the present invention.

FIGURE 2A is a broken-away detailed view of the pyrotechnic line according to the present invention.

FIGURE 2B is a broken-away detailed view of a pyrotechnic line according to an alternative embodiment of the present invention.

FIGURE 2C is a cross-sectional perspective view of a pyrotechnic line according to another embodiment of the present invention.

FIGURE 3 is a cross-sectional perspective view of the inflator of FIGURE 1.

FIGURES 4A and 4B are cross-sectional views of an inflator according to the present invention as utilized in an inflatable safety system according to the invention.

FIGURES 5A and 5B are respective side and cross-sectional views of an inflatable safety system in which an inflator according to the invention is used as a second generator in a conventional air bag device.

FIGURE 6 is a perspective view of an application of the invention to an door sidewall air bag.

FIGURE 7 is a perspective view of an application of the invention to an inflatable knee restraint.

FIGURES 8A and 8B are views of an application of the invention to a head impact protecting curtain.

FIGURE 9 is a side perspective view of a vehicle to which external airbags according to the invention are applied.

FIGURES 10A and 10B are views of an alternative application of the invention to an inflatable seat belt.

FIGURES 11A-11C are cross-sectional views of an inflatable seat belt according to the invention in respective pre-deployment, deploying, and fully deployed states.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The following description of the preferred embodiment is merely exemplary in nature, and is in no way intended to limit the invention or its application or uses.

An inflatable safety system 10 of the present invention is shown in FIGURE 1. The system 10 includes an inflator 20 disposed within an inflatable member 60. As described below, the inflator 20 includes a propellant material 24 (shown in FIGURES 2A and 2B) disposed within an inner member, preferably a resilient tube 22. An ignition assembly (for example, a squib) 40 is connected to one end of the tube 22 in proximity to the propellant 24. Ignition of the squib 40 ignites the propellant 24 at one end 22A, producing a pressure (shock) wave that propagates along the length of the propellant from the ignition end 22A to the other end 22B. The tube 22 maintains sufficiently high pressure to sustain combustion of the propellant 24 once it has been ignited in this fashion.

In the particular example shown in FIGURE 1, a plug or clamp 28 seals the far end of the tube 22, and endures the same high pressures as the interior surfaces of the tube 22. The plug 28 is made from any material in the art able to seal and endure at ambient and at high pressures. Alternative components for sealing the tube 22, such as a clamp, will be apparent to those skilled in the art.

Once the internal pressure of the tube 22 reaches a predetermined threshold, inflation gases produced by combustion of the propellant 24 are released through passages in the tube 22 into an outer member, preferably comprising a flexible tube 50. The tube 50 includes a plurality of spaced holes 52 which release the gas into the inflatable member 60 at a predetermined rate, pressure and direction. Thus, the tube 50 and the holes therein serve as a manifold to control the pressure, rate and direction of the inflation gases into the inflatable member 60.

As known in the art, the ignition assembly 40 may comprise any of several suitable devices to ignite the propellant 24. For example, the ignition assembly 40 may comprise an electric squib including a signal receiver, a filament, and an explosive material that ignites in response to an electrical signal generated in response to rapid deceleration of a vehicle. Only a small amount of explosive material, for example, less than 200 mg, is necessary to create the pressure wave. The explosive material may be made of zirconium-potasium-perchlorate (ZPP), titanium-potasium-perchlorate (TPP), or any other similar material known in the art.

The squib 40 operates according to technique well known in the art. For example, a sensor module (not shown) sends a signal to the receiver of the squib 40, for example, in response to rapid deceleration of a vehicle. Techniques for generation of such an electrical signal are well known in the art, and therefore are not described herein. An electrical current flows through a filament located within the squib. The filament generates heat and ignites the explosive material of the squib, thereby producing a pressure wave that travels down the length of the propellant 24, creating a flame front.

FIGURE 2A shows in more detail an illustrative embodiment of the inner member 22 that confines the propellant 24. In this example, the inner member 22 comprises an elongated, resilient tube having an external surface and an internal surface. The internal surface defines a cavity that contains a solid, gas

generating propellant 24. In this example, the propellant 24 coats the interior of the inner member 22. The propellant may comprise a single piece or a series of adjacent pieces. In this example, the propellant 24 has a center bore to permit a pressure wave to propagate along the length of the propellant 24 upon ignition with the squib 40.

In the example shown in FIGURE 2A, the tube 22 has a series of small holes 30 formed in its surface. These holes 30 are covered by a seal comprising individual pieces of sealant tape 32 that withstands a pressure of a predetermined threshold amount before breaking. For example, the seal may be designed to break at 100 to 200 bar. Upon breaking, the gases generated by combustion of the propellant 24 are released through the holes 30. In this way, the tube 22 provides sufficient internal pressure to facilitate combustion of the propellant 24.

In this embodiment, the holes 30 measure less than 1 mm in diameter, in 25 mm intervals, but other sizes and intervals may be used. During the combustion of the pyrotechnic material 24, the holes 30 may expand under the high pressure. The holes 30 allow a controlled escape of the gas into the resilient manifold 50.

An alternative embodiment is shown in FIGURE 2B. In this example, a rolled or extruded propellant material 24' is inserted into the tube 22. The exterior surface of the propellant 24' and the interior surface of the tube 22 define a gap 26'. The gap 26' provides a cavity through which a pressure wave propagates so as to ignite the propellant 24' along its length. It will be appreciated that the propellant 24' may additionally include a central bore, such as the central bore 26 shown in FIGURE 2A.

Whether either or both a center bore (as shown in FIGURE 2A) or a gap (as shown in FIGURE 2B) is used, the respective cross-sectional areas of the propellant 24 and the tube 22 should be optimized to achieve a desired propagation of the shock wave. A preferred ratio of cross-sectional areas of

propellant 24 and the tube 22 (measured from the inner diameter) may be in the range of .10-.60.

In the example of FIGURE 2B, the seal over the holes 30 comprises one large piece of sealant tape 32' that is placed over all of the holes 30. As in the example of FIGURE 2A, the tape 32' is comprised of an aluminum or steel material as known in the art. The tape may be replaced with any other material that prevents the loss of pressure through the holes 30 until a predetermined pressure has been reached.

It will be appreciated that other configurations for releasing the gas produced by the propellant from the inner member are possible. For example, as illustrated in FIGURE 2C, the inner member 22 includes a series of stress risers 34 that are designed to rupture once the internal pressure of the inner member reaches a predetermined threshold.

It will also be appreciated that the composition and the dimensions of the tube 22 may be modified depending upon the particular application for the inflator. In one embodiment, the tube 22 measures about 1 m long with a 6 mm outer diameter and 4 mm inner diameter. Preferably, the tube 22 is made of a non-metallic material that is sufficiently resilient to withstand the pressures of the ignition of the squib and combustion of the propellant. Further, the tube should have sufficient heat resistance to avoid undesired rupture throughout ignition of the squib and combustion of the propellant. The material that comprises the inner member 22 may comprise a single layer or multiple layers. One possible multilayer embodiment may comprise inner and outer layers of extruded, flexible plastic and an intermediate braided reinforcement layer of polyester, aramid, fiberglass or the like.

A preferred composition of the tube 22 that confines the propellant is illustrated in FIGURE 2C. In this example, the tube 22 is comprised of a flexible plastic or rubber compound 36 reinforced by a knitted fabric 38. The tube 22 may comprise any of a number of materials, such as latex, silicone,

polyurethane, or other materials sufficient to impede contamination of the propellant contained within.

The knitted fabric 38 allows the tube 22 to flex and to be fold or otherwise compress into the interior of a vehicle or other location, while providing sufficient strength to withstand relatively high internal pressures generated by the explosion of the explosive material in the electric squib 40 and by the combustion of the pyrotechnic material 24 that serves as a propellant for the igniter 10.

The propellant used in the invention generates sufficient gas to pressurize an inflatable member 60 within an acceptable amount of time. The propellant 24 should combust at a rate and temperature that is within an acceptable range (i.e., not too high). It should also have sufficient ability to propagate down a relatively long tube or other member that confines the propellant.. A minimum propagation rate of 100 m/s, and preferably about 500 m/s may be required to provide acceptable performance. It is preferable, that the propellant be characterized by a relatively high ratio of conversion of solids to gases. This characteristics reduces particle emission and may avoid the necessity of a separate filter. Additionally, the propellant 24 should not produce unacceptable amounts of carbon monoxide or other undesirable products. It will be appreciated that various propellants may meet some, or all of these criteria.

In various embodiments of the invention, propellant composition may include an azide material, a nitrocellulose material, a nitrate material or other suitable material. However, many other possible propellant compositions will be apparent to those skilled in the art. While such specific propellant compositions do not form a part of the invention as claimed herein, various alternative propellant compositions known to applicant are disclosed below. These propellant compositions may be generally described as comprising a fuel rich material, an oxidizer material and a porosity producing material that has one or more components that also constitute a binder system of the propellant.

Regardless of the configuration of the inflator according to the invention, the propellant 24 must generate sufficient gas to pressurize an inflatable member 60 within an acceptable amount of time. The propellant 24 should combust at a rate and temperature that is within an acceptable range (i.e., not too high). It should also have sufficient ability to propagate down a relatively long tube or other member that confines the propellant.. A minimum propagation rate of 100 m/s, and preferably about 500 m/s may be required to provide acceptable performance. It is preferable, that the propellant be characterized by a relatively high ratio of conversion of solids to gases. This characteristics reduces particle emission and may avoid the necessity of a separate filter. Additionally, the propellant 24 should not produce unacceptable amounts of carbon monoxide or other undesirable products. It will be appreciated that various propellants may meet some, or all of these criteria.

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As shown in FIGURES 1 and 3, the outer member preferably comprises a tube 50 that surrounds the inner tube 22 that contains the propellant 24. In this embodiment, the tube 50 includes a series of holes 52 which serve as exhaust ports to control release of inflation gases received from the inner member 22. This distributes the gas more uniformly and controls the timing of the rate, pressure, and direction of the gases that inflate the inflatable member 60.

As with the inner member 22, the outer member 50 preferably is also made of a resilient, high-temperature non-metallic material. Most preferably, it is comprised of a flexible material, such as a knitted fabric which allows the outer member 50 to fold and expand so that it can easily be incorporated into various locations in or on a vehicle.

In many applications, after the combustion process, the gas generated by combustion of the propellant will release at a relatively high pressure, such as 200 bar. This pressure is typically too high for proper inflation of the inflatable member 60. By proper distribution of the holes in the outer tube 50, the outer tube 50 may serve to reduce the pressure rise rate to an acceptable level. For example, by selection of the proper size and distribution of the holes in the outer member, gas entering the outer member 50 at a relatively high pressure may exit at a significantly lower pressure into the inflatable member 60. The manifold 50 may also be used to direct the passage of the gas into the inflatable member 60 along a predetermined direction.

Because of the resiliency of the inner member 22 and the outer member 50, the inflator 20 of the present invention may be used in a variety of applications. In addition to various air bag implementations, such applications may include mounting the system 10 within a seat belt, a headliner, a knee bolster, or a carpet within the vehicle. Alternatively, the invention may be used to inflate a cushion released external to the vehicle to reduce damage from a collision or injury to a pedestrian.

In each of the various embodiments and applications of the invention, it will be understood that the inflator may be triggered in accordance with techniques well known in the art, such as with a sensor that detects rapid deceleration of a vehicle and produces a signal that triggers a squib dispose within the inflator, as described above. Various specific applications and embodiments of the invention are now briefly described.

As shown in FIGURES 5A and 5B, the system 10 may be used as a second gas generator in a conventional air bag device. In these examples, a conventional air bag device 80 may be mounted within a steering wheel 82. A pyrotechnic line 20 is coiled around the convention air bag device 80 and generates gas at an instant either before, during or after the generation of gas by the conventional air bag device 80. In this way, the combination of the conventional air bag device 80 and the pyrotechnic line 20 supply a two-stage deployment of one inflatable cushion 60'.

FIGURES 4A and 4B show, respective front and cross-sectional views of an inflator and inflatable member 60 which may be applied to various locations. For example, such embodiment may be deployed within a vehicle as shown in FIGURES 6, 7, and 8A-8B.

FIGURE 6 illustrates the location of a door sidewall air bag 162 in an inflatable safety system according to an embodiment of the invention. In this example, the sidewall air bag 162 is deployed above the arm rest 164 and hand grip 166 of a vehicle.

FIGURE 7 illustrates the location of an inflatable knee restraint 172 in an inflatable safety system according to another embodiment the invention. In this example, an inflated cushion 174 is deployed proximate to the knee of a vehicle occupant 176.

FIGURES 8A and 8B illustrate a head impact protecting curtain in an inflatable safety system according to another embodiment of the invention. In this example, an inflator according to the invention inflates an inflatable member 60 disposed within the head curtain proximate to the head of a vehicle occupant. The deployed position of the inflatable cushion is illustrated with dashed lines (reference numeral 182).

FIGURE 9 illustrates an inflatable safety system according to the invention located to deploy a cushion external to the vehicle. In this example,

there are shown both an external side airbag 192 and a pedestrian protection or pre-collision bag 194.

FIGURES 10A and 10B illustrate an inflatable seat belt in accordance with an embodiment of the invention. In this example, a belt 110 includes an inflatable section 112. The inflatable section 112, when inflated, serves to cushion the occupant and to tension the belt against the occupant. FIGURES 11A-11C illustrate a cross section of such inflatable seat belt in respective pre-deployment, deploying, and fully deployed states.

As mentioned above, the invention may be practiced using a variety of different propellant compositions. One possible propellant composition is characterized as being part of a pure pyrotechnic inflator. A pure pyrotechnic inflator refers to an inflator in which substantially entirely all gases provided by the inflator are propellant gases generated by the solid gas-generating propellant. For a pure pyrotechnic inflator, there is no need to store a pressurized gas or medium and the inflator is free of, or does not have, a stored, pressurized gas. The propellant may have a composition that is substantially free of metals so that the propellant gases are substantially free, or in the absence of, metal-containing particulate and/or condensable materials, eliminating the need for a filter to remove any such particulate and/or condensable materials. Furthermore, it may be preferable to utilize a propellant that is substantially free of halogen-containing materials so that the propellant gases are substantially free, or in the absence, of halogen-containing components.

As mentioned above, it may be preferred to utilize a propellant that include at least a fuel-rich material, an oxidizer material and a porosity producing material, which has one or more components that also constitute a binder system of the propellant. The fuel-rich material refers to a material that contains oxygen in its molecular structure, if at all, in an amount that is smaller than a stoichiometric amount of oxygen that would be required, during a self-sustained combustion reaction, to convert all hydrogen that may be in the fuel-

rich material to water and to convert all carbon that may be in the fuel-rich material to carbon dioxide. If the fuel-rich material were combusted alone, it would produce gaseous decomposition products including a significant amount of carbon monoxide and/or hydrogen, both of which are undesirable for purposes of inflating an inflatable or air bag located in a vehicle. In one embodiment, the fuel-rich material has a primary component that is a majority, by weight, of the fuel-rich material. In one embodiment, the primary component of the fuel-rich material is a gun-type propellant. Gun-type propellants, as used herein, constitute secondary explosives and are high-temperature, fuel-rich components such as single, double, or triple-based propellants and nitramine propellants such as LOVA (low vulnerability ammunition) and HELOVA (high energy, low vulnerability ammunition) propellants. Such gun-type propellants have a combustion temperature in the range from about 2500 K to about 3800 K and typically greater than about 3000 K. Examples of suitable gun-type propellants include nitramine-based propellants having as major ingredients RDX (also known as hexahydrotrinitrotriazine or cyclotrimethylene trinitramine) or HMX (also known as cyclotetramethylenetethranitramine). PETN (also known as pentaerythritol tetranitrate) and TAGN (also known as triaminoguanadine nitrate) could also serve as major ingredients in gun-type propellants. Other suitable gun-type propellants include those incorporating tetrazole-based compounds and triazole-based compounds, particularly five-aminotetrazole. Another fuel-rich material that is acceptable is nitroguanidine, which is the preferred primary component of the fuel-rich material for inflators having lengths comparable to their widths. It may be preferred because nitroguanidine has a characteristic burn rate exponent (n) that is less than 1, unlike fuel-rich materials that have a characteristic burn rate exponent of about 1, e.g., RDX or HMX. For fuel-rich materials with an exponent of about 1, there is substantially greater difficulty in controlling their combustion stability. For inflators having their lengths about five times greater than their widths, on the other hand, fuel-rich materials with n

equal to, or substantially equal to, 1 (e.g. RDX and HMX) may be preferred in order to sustain combustion. Regardless of which fuel-rich material is employed, the amount, by weight, of the secondary explosive of the fuel-rich material in the propellant is preferably at least 5% and, preferably, no greater than about 30% of the propellant.

The oxidizer material may comprise a nitrate compound that is free of metal-containing constituents so that the propellant gases, which are generated when the propellant is combusted, are substantially free, or in the absence, of metal-containing particulate and/or condensable materials. The oxidizer material provides oxygen for oxidizing decomposition products of the fuel-rich material so that at least some of the hydrogen and/or carbon monoxide generated by the fuel-rich material during a combustion reaction will be oxidized to water and/or carbon dioxide, respectively. The oxidizer material of the propellant is defined as a material capable of supplying oxygen to increase the ultimate yield of carbon dioxide and/or water from combustion products of the fuel-rich material and thereby reduce the ultimate yield of carbon monoxide and/or hydrogen from combustion of the fuel-rich material. More specifically, the oxidizer material may comprise only elements selected from the group consisting of carbon, oxygen, nitrogen and hydrogen and, most preferably, the oxidizer material comprises only the elements of nitrogen, oxygen and hydrogen. Examples of possible materials for use as the oxidizer material include oxygen-containing ammonium salts, such as ammonium nitrate and ammonium dinitramide. Ammonium nitrate may be the particularly preferred oxidizer material. The amount of oxidizer material in the propellant, by weight, is in the range of about 50%-90%.

The porosity producing material that includes a binder system of the propellant is provided to accommodate the phase change that the oxidizer material, such as ammonium nitrate, undergoes when subject to temperature changes, such as numerous temperature cycling from less than -30 C to more

than 80 C, e.g. 15 or more of such cycles. Ammonium nitrate undergoes a crystalline phase change and also a volume change accompanying the phase change during normal storage conditions. The porosity producing material provides a porous propellant composition when mixed or otherwise combined with the other materials of the propellant so that the porosity, by volume, of the resulting propellant is at least about 15% and, preferably, in the range of about 15%-40% (about 85%-60% of theoretical density). The porosity producing material preferably includes naturally occurring fibrous cellulose. Fibrous cellulose is a commonly available component, such as that available from pulp board or wood pulp that is typically used in paper making processes. The fibrous cellulose is comprised of a number of fibrous cellulose pieces or fibers. Each of the pieces has a length and a width and the lengths of the fibrous cellulose pieces are at least five times greater than their widths. In that regard, the widths of the fibrous cellulose pieces are in the range of about 2.5 microns - 250 microns and the lengths of the fibrous cellulose pieces are in the range of about 1,000 microns - 10,000 microns. The fibrous cellulose pieces are also different from non-fibrous cellulosic material such as nitrocellulose, cellulose acetate, and cellulose acetate butyrate. Consequently, fibrous cellulose or any fibrous cellosic material is included in a group that is acceptable as a component of the porosity producing material, while non-fibrous cellulosic materials are excluded from the group of acceptable components of the porosity producing material.

With respect to the binder system of the porosity producing material, it may include hydroxypropyl- cellulose (HPC), although other known or conventional binder products could be utilized. The HPC contributes to suspending the solid ingredients of the propellant composition in connection with providing the appropriate rheology for extrusion. Other contributors to the binder system are the fibrous cellulose and a dispersal agent.

In addition to being part of the binder system, the dispersal agent is included in the propellant composition and works together with the HPC (or other appropriate component) for preventing unwanted agglomerating or clumping of the fibrous cellulose during the mixing process with other materials of the propellant. In particular, it has been observed or determined that, when mixing the materials to form the propellant, unwanted clumping or gathering of the fibrous cellulose into "balls" occurs. Such clumping is not acceptable in providing a uniform propellant composition. It is known to utilize a relatively large amount of carrier fluid, such as a solvent (e.g. alcohol based), in connection with mixing the propellant materials. However, prior to extruding or completing the formation of the propellant or propellant pieces, it is necessary to remove or evaporate the carrier fluid. This adds considerably to the cost and time involved with the propellant manufacturing process. In order to eliminate or substantially reduce these costly steps, while avoiding unacceptable clumping of the fibrous cellulose, a dispersal agent has been identified that disperses fibrous cellulose or otherwise prevents the fibrous cellulose from clumping together during the mixing process. Although not intended to be limited to a particular theory, it is believed that the dispersal agent acts in somewhat of a mechanical manner to separate or maintain separation of fibrous cellulose particles or pieces. The sizes of the dispersal agent pieces are substantially smaller than the sizes of the fibrous cellulose pieces. Preferably, the widths or diameters of the fibrous cellulose pieces are at least five times greater than the widths or diameters of the dispersal agent pieces. In one embodiment, the widths of the dispersal agent pieces are in the range of about .05-.5 micron. In a preferred embodiment, the dispersal agent includes a product identified as Cellulon.

Yet another component of the porosity-producing material may be a viscous liquid carrier that includes a solution of a plastic polymer and a solvent, for example, a solution of about 10%-30% by weight of the HPC and about

90%-70% by weight of alcohol or alcohol-water azeotrope. The liquid carrier facilitates the dispersal of the first and second components into a dough-like mixture. This provides the appropriate rheology for extrusion of the propellant.

Optionally, the porosity producing composition also includes colorant in substantially minor amounts. When included, the colorant functions to distinguish propellant configurations or lots.

When making the propellant, the fuel-rich material, the oxidizer material and the porosity producing composition including binder system are mixed together using a conventional and known process. Subsequent to the mixing, propellant or propellant pieces are extruded. The formed propellant is a uniform or homogenous mixture or combination of the included materials. After extrusion, each propellant piece has a uniform composition throughout its length, with the fibrous cellulose pieces or fibers essentially remaining the same size that they had before being mixed with the other of the propellant components. In particular, throughout the entire cross-section of any selected cross-section of a propellant piece or propellant, there is a substantially uniform mixture of the included materials. For example, for each selected cross-section along the length of the propellant, any at least 1,000-micron portion of any selected cross-section has the same homogenous composition as any other at least 1,000-micron portion of the same selected cross-section. Such a uniform mixture or composition may be found in any 100-micron portion of the same selected cross-section of the propellant.

The following examples of propellants are known to applicant:

EXAMPLES

Example 1

A solid gas-generating propellant composition is comprised of the following materials or components, by weight percentage:

Ammonium Nitrate (200 mesh)	53.00%

Strontium Nitrate (200 mesh)	15.00%
RDX (20 micron, screened 200 mesh)	20.00%
Cellulose (estercell) 1861	5.00%
Cellulon (16.8% solids)	2.00%
Hydroxypropylcellulose (medium grade) (HPC)	5.00%
Colorant	0.01%

The components or materials of such a propellant are mixed with solvent comprising 90% n-propyl alcohol and 10% water. The solvent comprises about 18% of the mixture weight. From this mixture that includes the solvent and water, propellant pieces can be extruded. The extruded propellant is semi-rigid but has a porosity characteristic or property, with the porosity being at least about 15% by volume and preferably about 40%. This property of the propellant accommodates thermal expansion due to crystalline phase changes of the ammonium nitrate without sacrificing the desired degree of rigidity. The binder system of the propellant includes the cellulose, the HPC and the Cellulon(R) product. The HPC is an alcohol soluble polymer and contributes desired viscosity to the propellant composition in connection with providing the desired extruded propellant pieces.

Example 2

Like Example 1, the propellant composition includes RDX as the fuel-rich material. The materials or components, by weight, for this example are as follows:

Ammonium Nitrate (200 mesh)	70.00%

RDX (20 micron, screened 200 mesh)	20.00%
Cellulose (estercell) 1861	4.50%
Cellulon (16.8% solids)	1.00%
Hydroxypropylcellulose (medium grade) (HPC)	4.50%
Methyl violet	0.01%

The propellant of Example 2 meets thermal stability requirements and temperature cycling tests, as does the propellant of Example 1. In particular, each of these two propellant compositions remains functional in the inflator with which they are used, after being subjected to a temperature of 107 C for a period of 400 hours. Such functionality means that the propellant ignites when acceptably exposed to an appropriate signal, after being subjected to such time and temperature conditions. With regard to temperature cycling tests, the propellant remains functional when it is subjected to a number of cycles of temperature changes between temperatures that are greater than 80 and less than -30 C.

Example 3

The propellant of this example is characterized by replacement of RDX as the fuel-rich material by one or more other secondary explosives and, in this case, by nitroguanidine.

Ammonium Nitrate (200 mesh)	80.00%
1-Nitroguanidine	9.00%
Cellulose (estercell) 1861	6.00%

Cellulon (16.8% solids)	1.00%
Hydroxypropylcellulose (medium grade) (HPC)	4.00%
Methyl violet	0.01%

In addition to the nitroguanidine as a replacement for RDX, the secondary explosives of HMX, PETN, or the like could be utilized. The HPC could be replaced by other organic binders, such as other cellulose esters, vinyl acetate and/or polyvinyl alcohol, acrylic polymers and the like.

Example 4

Another propellant that includes 1-nitroguanidine as the primary component of the fuel-rich material has the following materials or components:

Ammonium Nitrate (200 mesh)	77.50%
1-Nitroguanidine	15.00%
Cellulose (estercell) 1861	3.50%
Cellulon (16.8% solids)	1.00%
Polyacrylate polymer	3.00%
Colorant	0.01%

Like the propellant compositions of Examples 1 and 2, the propellants of Examples 3 and 4 also pass thermal stability testing. It is also noted that each of the propellant compositions of Examples 1-4 can be used in varied and differently configured pure pyrotechnic inflators. In that regard, such propellant

compositions can be used in known or conventional pyrotechnic inflators, as well as the new pyrotechnic inflator designs disclosed later herein. Additionally, although polyocrylate is the binder component used in this example, other conventional or known binders could be employed such as polyurethane and HTPB.

The present invention provides several advantages in comparison with prior inflators for vehicles. For example, the inflator according to the invention utilizes a shock wave principle to ignite the propellant directly and propagate the ignition through the entire length of the propellant bed. Thus, in contrast to conventional inflators that rely on heat and burning particles to ignite a propellant bed, the inflator according to the invention initiates the generation of inflation gases from combustion of the propellant without the need for a booster propellant.

Additionally, with the invention, the inner tube that confines the propellant during combustion and the flexible outer member that controls and directs the release of inflation gases into the inflatable member, obviate the need of a metal combustion housing. Further, depending on the composition of the propellant, the need for a metallic filter component may also be avoided. As a result the invention utilizes fewer components, thereby reducing the overall material and assembly cost of the inflator. The use of relatively soft, primarily non-metallic components also facilitates compliance with safety considerations for such applications as curtain inflators and knee bolsters.

The foregoing discussion discloses and describes preferred embodiments of the present invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that changes and modifications can be made to the invention without departing from the true spirit and fair scope of the invention as defined in the following claims. For example, it will be appreciated that many different types of propellants may be utilized. Additionally, the size and shape of the inner and outer members may be altered.

Thus, while preferably a tubular shape is contemplated, others are possible. Further, the number, size and distribution of the passages used to release gas generated by propellant combustion may be varied depending on the application.

WHAT IS CLAIMED IS:

1. An inflator for a vehicle comprising:

a propellant for generating inflation gases;

an inner member confining the propellant;

an igniter disposed proximate said propellant to ignite the propellant, the igniter including a cavity through which a pressure wave travels;

an outer member covering the inner member, the outer member controlling flow of inflation gases released from the inner member resulting from the combustion of the propellant.

2. The inflator of claim 1, wherein the propellant is a solid pyrotechnic material with a high conversion of solid to gas.

3. The inflator of claim 1, wherein the propellant is coated on an internal surface of the inner member.

4. The inflator of claim 1, wherein the propellant is extruded.

5. The inflator of claim 1, wherein the inner member is substantially non-metallic.

6. The inflator of claim 5, wherein the inner member is comprised of a flexible rubber material.

7. The inflator of claim 6, wherein the inner member is reinforced by a knitted fabric.

8. The inflator of claim 5, wherein the inner member is comprised of a flexible plastic material.

9. The inflator of claim 8, wherein the inner member is reinforced by a knitted fabric.

10. The inflator of claim 1, wherein the outer member is substantially non-metallic.

11. The inflator of claim 10, wherein outer member is comprised of a fabric.

12. The inflator of claim 11, wherein the fabric material is knitted.

13. The inflator of claim 1, wherein the outer member comprises a flexible material that expands upon receiving inflation gases from the inner member.

14. The inflator of claim 1, wherein the inner member includes a surface having a plurality of spaced holes through which the inflation gases are released into the outer member once internal pressure of the inner member reaches a predetermined threshold.

15. The inflator of claim 14, wherein the outer member releases inflation gas into an inflatable member at a pressure lower than the predetermined threshold of the inner member.

16. The inflator of claim 1, wherein the inner member is constructed so as to rupture at one or more locations in a surface thereof once internal pressure of the inner member reaches a predetermined threshold, thereby releasing inflation gases into the outer member.

17. The inflator of claim 16, wherein the outer member releases inflation gas into an inflatable member at a pressure lower than the predetermined threshold of the inner member.

18. The inflator of claim 1, wherein the outer member includes a surface having a plurality of spaced holes that direct passage of the inflation gas into an inflatable member in a predetermined distribution.

19. The inflator of claim 1, wherein the inner member comprises a resilient, elongated tube.

20. The inflator of claim 1, wherein the outer member comprises an elongated tube.

21. The inflator gas generator of claim 1, wherein the propellant comprises an azide material.

22. The inflator gas generator of claim 1, wherein the propellant comprises a nitrocellulose material.

23. The inflator gas generator of claim 1, wherein the propellant comprises a nitrate material.

24. The inflator of claim 1, wherein the inner member includes a seal with a predetermined release pressure located over passages formed in a surface of the inner member to prevent release of the inflation gas until internal pressure of the inner member reaches a predetermined threshold.

25. An inflatable safety system for a vehicle, comprising:

a propellant for generating inflation gases;

an elongated, resilient tube surrounding said propellant, said tube including a cavity through which a pressure wave travels;

an igniter located at one end of said propellant for igniting said propellant upon receipt of a signal; and

an inflatable member that receives said inflation gases.

26. The inflatable safety system of claim 25, further comprising a manifold disposed between said resilient tube and said inflatable member, wherein said manifold directs the passage of the gas into said inflatable cushion at a controlled rate.

27. The inflatable safety system of claim 26, wherein said manifold is substantially non-metallic.

28. The inflatable safety system of claim 26, wherein said manifold is comprised of a flexible fabric.

29. The inflatable safety system of claim 28, wherein said fabric is knitted.

30. The inflatable safety system of claim 25, wherein said elongated, resilient tube is substantially non-metallic.

31. The inflatable safety system of claim 25, wherein said elongated, resilient tube is comprised of a flexible rubber material.

32. The inflatable safety system of claim 31, wherein said flexible rubber material is reinforced by a knitted fabric.

33. The inflatable safety system of claim 25, wherein said elongated, resilient tube is comprised of a flexible plastic material.

34. The inflatable safety system of claim 33, wherein said flexible plastic material is reinforced by a knitted fabric.

35. The inflatable safety system of claim 25, wherein said inflatable member is disposed within a seat belt restraint that expands upon rapid deceleration of the vehicle.

36. The inflatable safety system of claim 25, wherein the inflatable member is disposed within a knee bolster that expands upon detection of a rapid deceleration of the vehicle.

37. The inflatable safety system of claim 25, wherein the inflatable member is disposed within the door sidewall trim of the vehicle, said inflatable member expanding upon detection of a rapid deceleration of the vehicle.

38. The inflatable safety system of claim 25, wherein the inflatable member is disposed above the side windows of the vehicle, said inflatable member expanding upon detection of a rapid deceleration of the vehicle.

39. The inflatable safety system of claim 25, wherein the inflatable member is mounted externally to the vehicle and said signal is generated by a collision sensor to inflate the inflatable member prior to impact of the vehicle with an object or person.

40. An inflator for a vehicle comprising:

an elongated tube having an interior portion;

a propellant confined within the interior of said elongated tube for generation of inflation gases;

an igniter disposed at one end of the propellant, said igniter generating a pressure wave that propagates through the interior of the elongated tube and ignites said propellant.

41. An inflator according to claim 40, further comprising an outer member covering said elongated tube, wherein said outer member directs release of said inflation gases into an inflatable member.

42. An inflator according to claim 41, wherein said outer member is comprised of a flexible, non-metal material.

43. An inflator according to claim 41, wherein the inflatable member is disposed within the door sidewall trim of the vehicle, said inflatable member expanding upon detection of a rapid deceleration of the vehicle.

44. An inflator according to claim 41, wherein the inflatable member is disposed above the side windows of the vehicle, said inflatable member expanding upon detection of a rapid deceleration of the vehicle.

45. An inflator according to claim 41, wherein the inflatable member is mounted externally to the vehicle and said signal is generated by a collision sensor to inflate the inflatable member prior to impact of the vehicle with an object or person.

46. An inflator according to claim 41, wherein said outer member is substantially non-metallic.

47. An inflator according to claim 40, wherein said propellant is coated on an internal surface of said elongated tube.

48. An inflator according to claim 40, wherein said propellant is comprised of an extruded, elongated pyrotechnic material.

49. An inflator according to claim 40, wherein said propellant is a solid pyrotechnic material with a high conversion of solid to gas.

50. An inflator according to claim 40, wherein said elongated tube is substantially non-metallic.

51. An inflator according to claim 1, wherein said cavity is formed within said propellant.

52. An inflator according to claim 1, wherein said cavity is formed between an exterior surface of said propellant and an interior surface of said inner member.

53. The inflatable safety system of claim 25, wherein said cavity is formed within said propellant.

54. The inflatable safety system of claim 25, wherein said cavity is formed between an exterior surface of said propellant and an interior surface of said elongated, resilient tube.

55. An inflator according to claim 40, wherein said cavity is formed within said propellant.

56. An inflator according to claim 40, wherein said cavity is formed between an exterior surface of said propellant and an interior surface of said elongated tube.

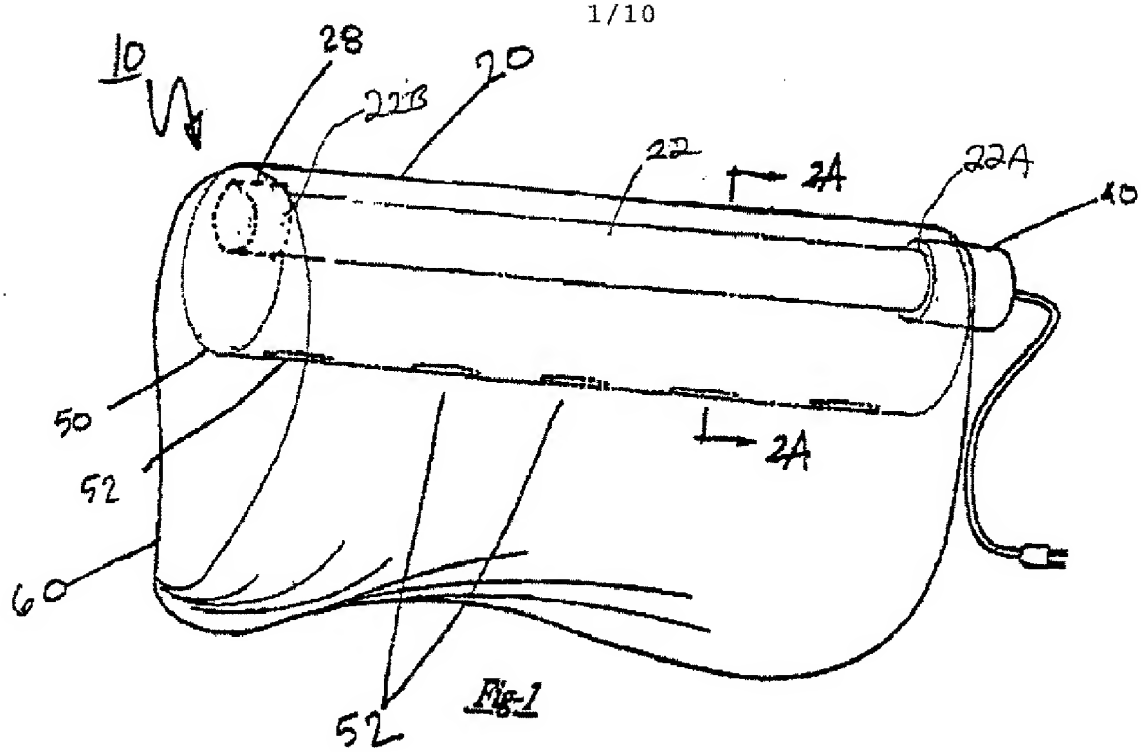


Fig-1

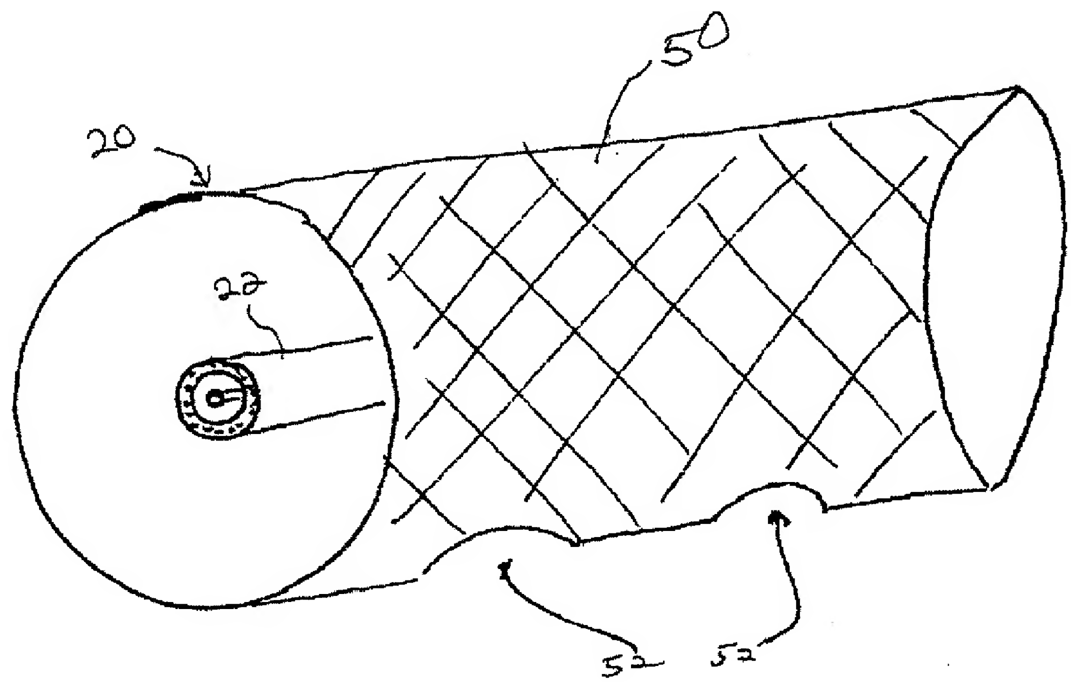


FIGURE 3

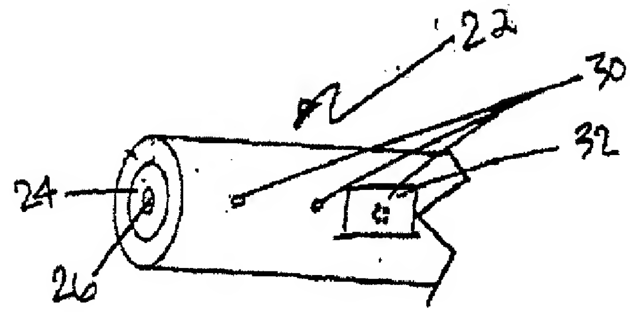


Fig-2 A

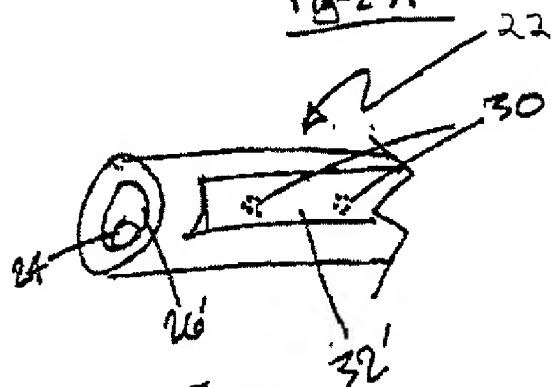


Fig-2B

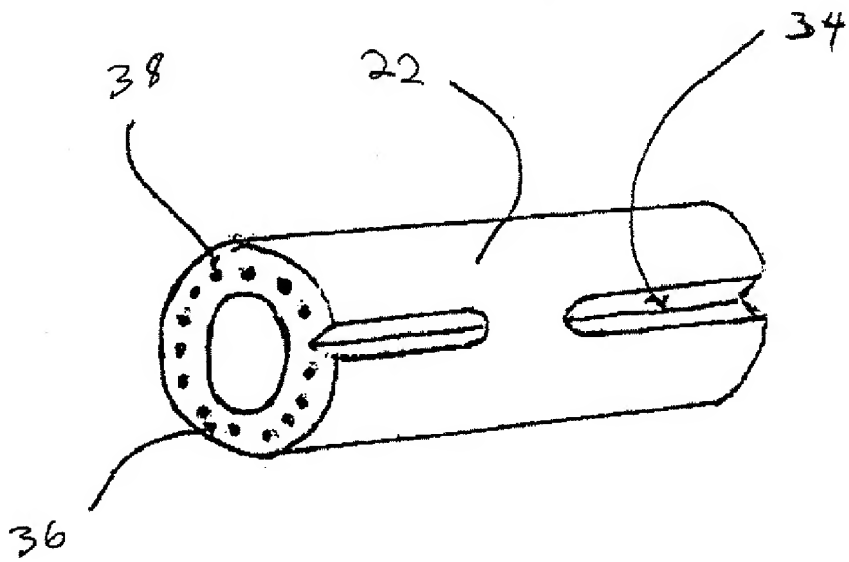
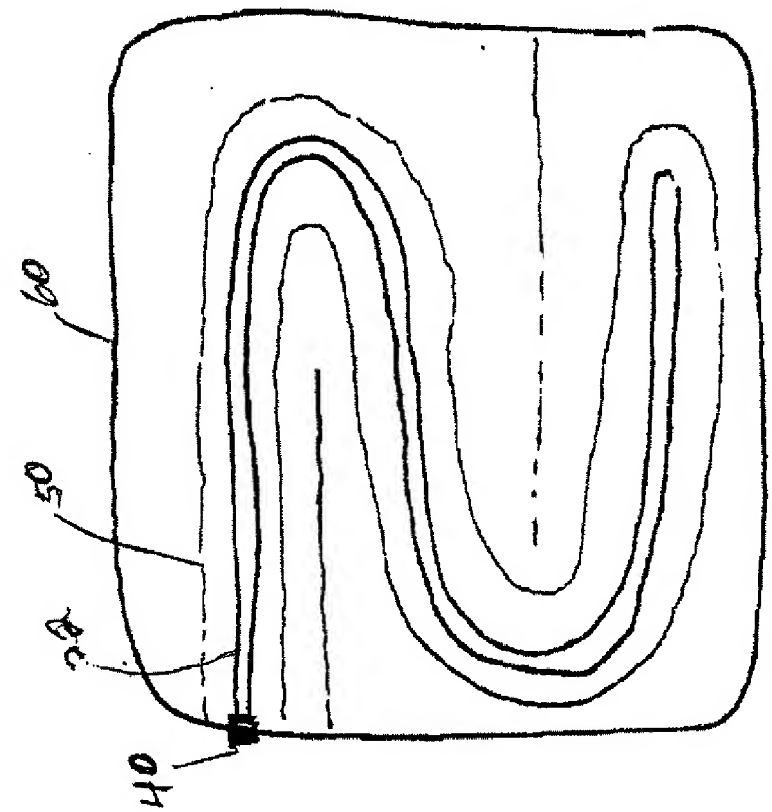


FIGURE 2C

FIGURES 4B



FIGURES 4A

INFLATABLE TRIM / CARPET / KNEE RESTRAINT

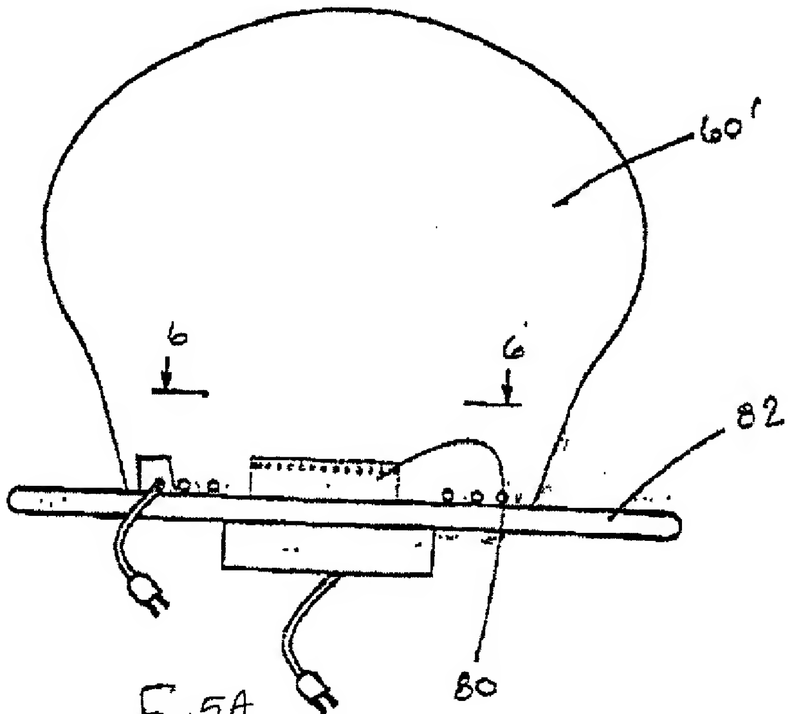


Fig.5A

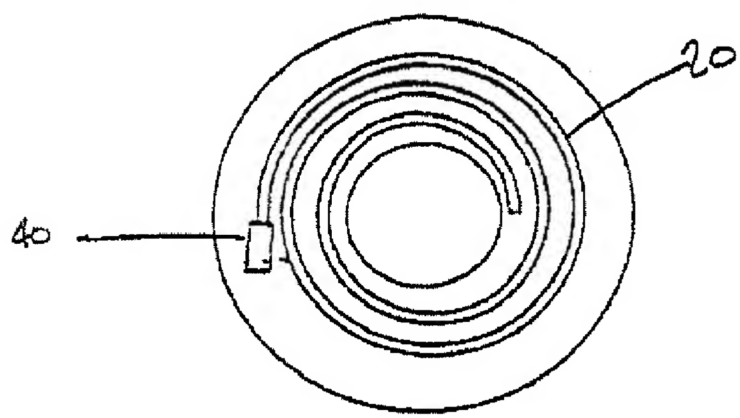


Fig-5B

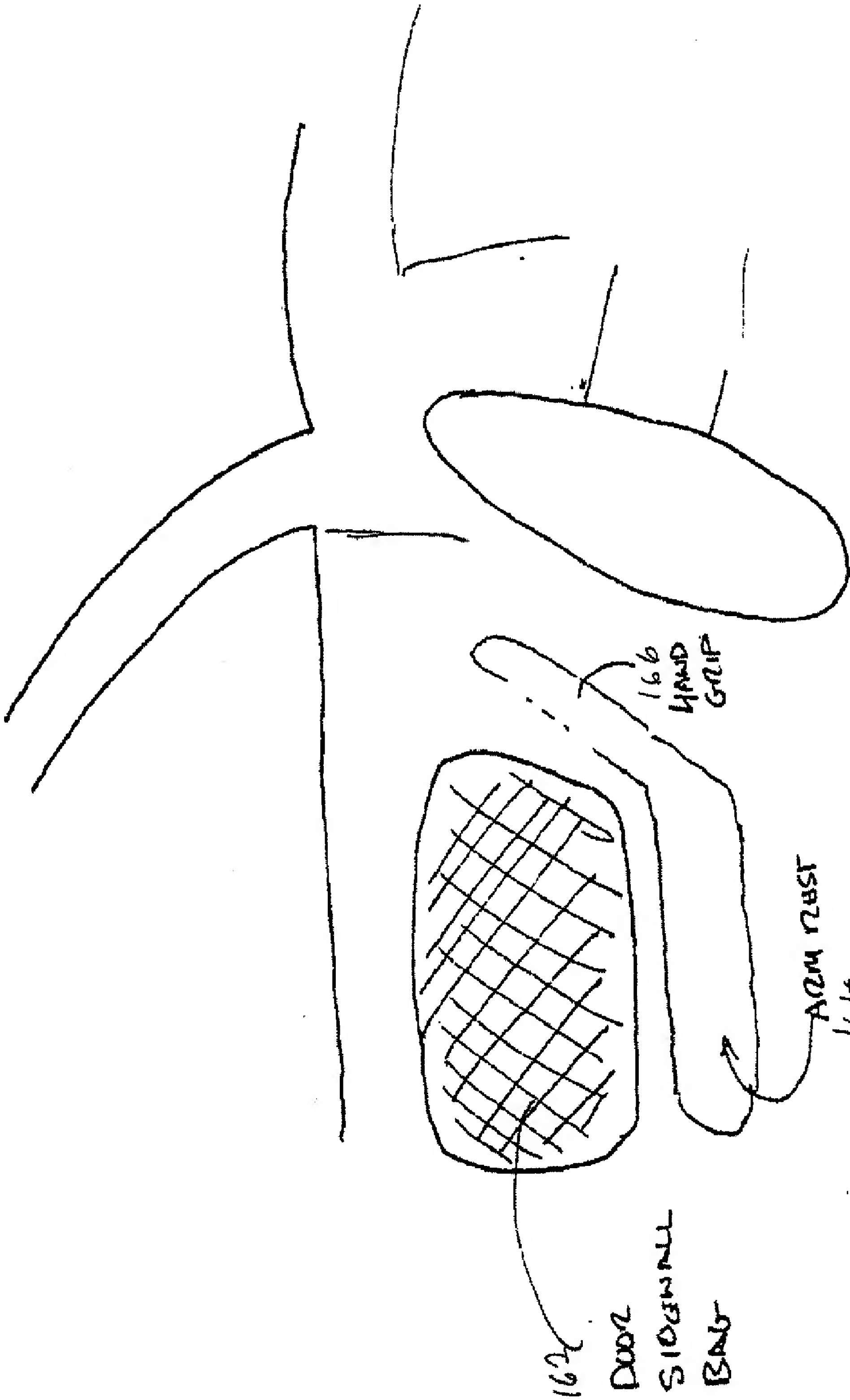


FIGURE 6
INFLATABLE DOOR SIDEWALL TRIM DEPLOYED LOCATION

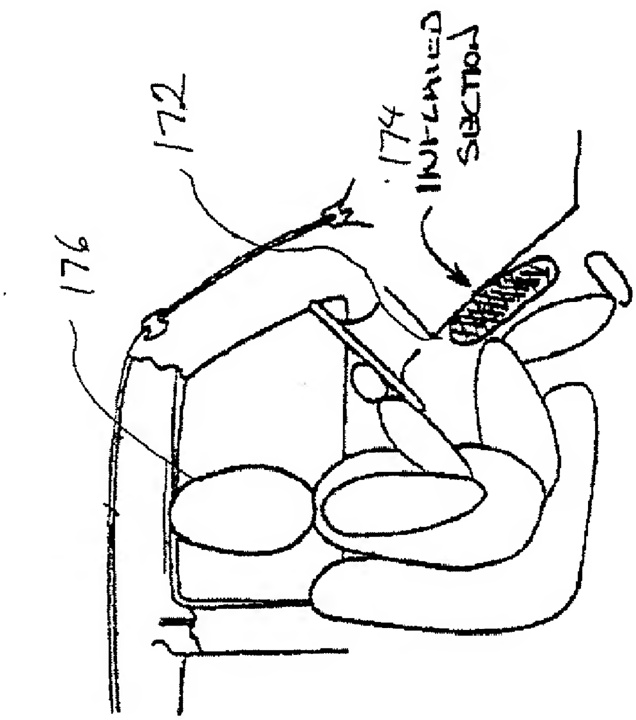


FIGURE 7

INFLATABLE KNEE RESTRAINT

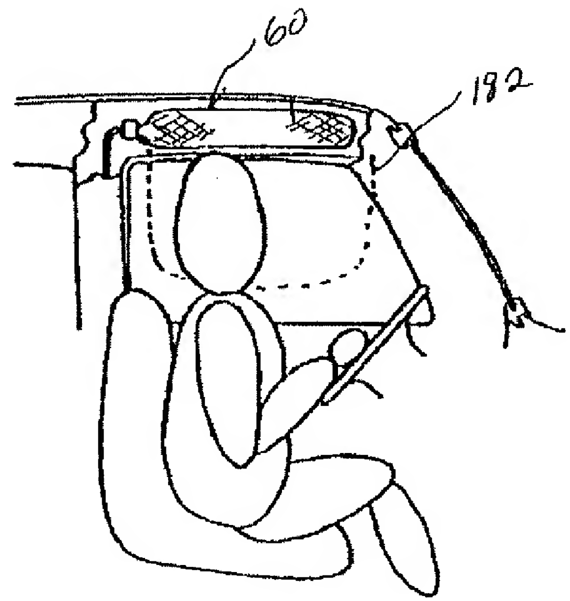


FIGURE 8A

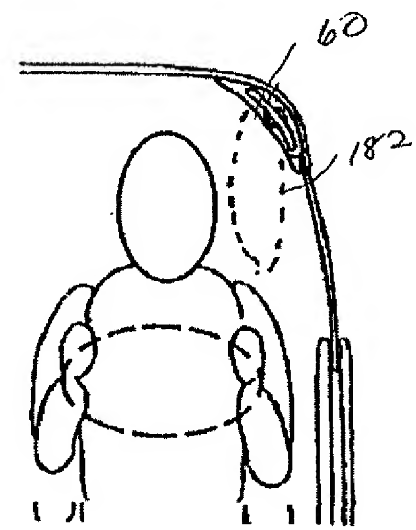


FIGURE 8B

HEAD IMPACT PROTECTING CURTAIN

STOWED LOCATION AND DEPLOYED POSITION SHOWN (DOTTED LINES)

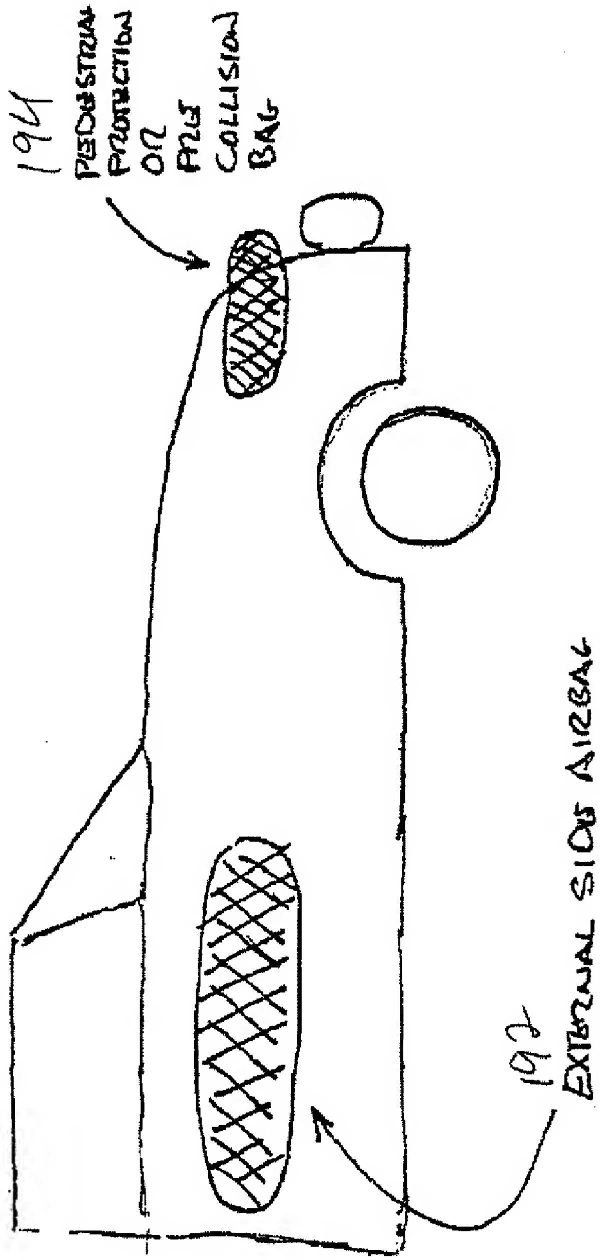


FIGURE 9

EXTERNAL AIRBAG LOCATIONS

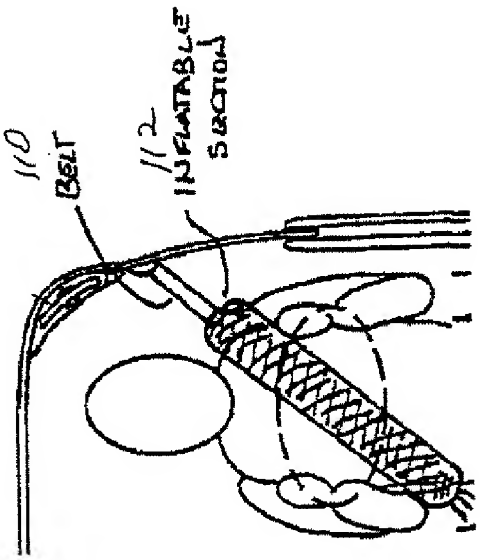


FIGURE 10B

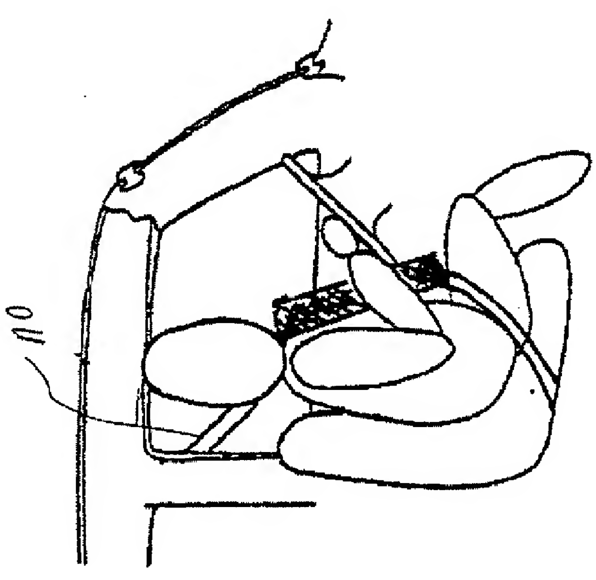


FIGURE 10A

INFLATABLE SEAT BELT

PRE DEPLOYMENT DEPLOYING FULLY DEPLOYED

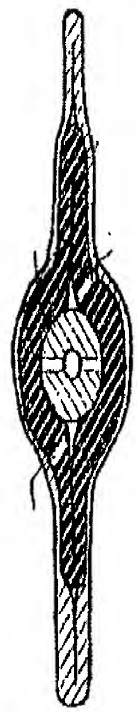


FIGURE 11A

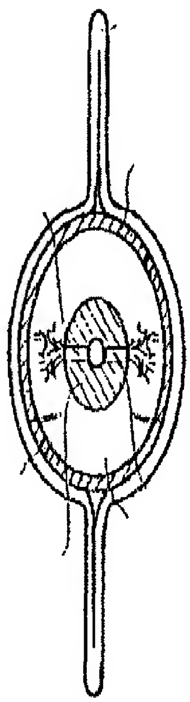


FIGURE 11B

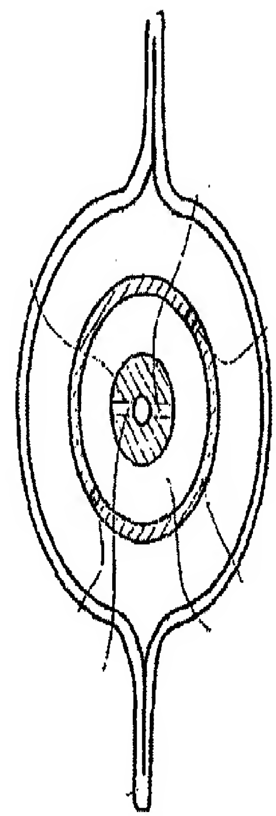


FIGURE 11C

INFLATABLE SEATBELT

CROSS SECTIONS

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/25586

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60R21/26 B60R21/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 276 (M-0984), 14 June 1990 (1990-06-14) & JP 02 081747 A (ASAHI CHEM IND CO LTD), 22 March 1990 (1990-03-22) abstract	1-3,16
Y		5,6,8

Y	PATENT ABSTRACTS OF JAPAN vol. 014, no. 042 (M-0925), 25 January 1990 (1990-01-25) & JP 01 273748 A (ASAHI CHEM IND CO LTD), 1 November 1989 (1989-11-01) abstract; figures 1-3	5,6,8
A		1-3

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 March 2000	07/04/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dubois, B

1

INTERNATIONAL SEARCH REPORT

Int .tional Application No
PCT/US 99/25586

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 41 26 743 A (HERRMANN GUENTER) 18 February 1993 (1993-02-18)	1,4,5,8, 16-20, 23,25, 26,30, 33,40, 41,48, 50-56
	column 1, line 42 - line 48 column 2, line 16 - line 23 column 2, line 45 - line 61; figures 3-5 ---	
Y	US 4 220 087 A (POSSON PHILIP L) 2 September 1980 (1980-09-02)	1,4,5,8, 16-20, 23,25, 26,30, 33,40, 41,48, 50-56
	abstract column 2, line 1 - line 43; figure 1	
A	column 2, line 62 - line 68 column 4, line 49 - line 56; figures 2,3 column 5, line 4 - line 6; figure 5 ---	3,47
Y	DE 41 34 995 C (HERRMANN, GÜNTER) 18 March 1993 (1993-03-18)	1,2,4,5, 8,16,17, 19,20, 23,25, 26,30, 33,38, 40,41, 44, 48-50, 52,54,56
	column 1, line 19 - line 37 column 1, line 61 -column 2, line 7; figures ---	
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